CHAPTER TWO

GEODETIC SURVEYS

BUREAU OF DESIGN AND ENVIRONMENT

SURVEY MANUAL

May 2001

CHAPTER TWO

GEODETIC SURVEYS

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CHAPTER TWO

GEODETIC SURVEYS

I. INTRODUCTION TO GEODETIC REFERENCE FRAMEWORKS

A. THE NEED FOR GEODETIC CONTROL

In order to permit the many and varied surveying, mapping and charting programs to be referenced to some common system, it is necessary to have a common reference framework of control points. An accurate framework can be useful for the various levels of users.

A.1 Federal
At the federal level the National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), the parent agency of the National Geodetic Survey (NGS), publishes aeronautical charts, and ocean navigation charts while the US Geological Survey publishes various scales of quadrangle maps covering the entire nation. All of these products have a common reference system.

A.2 State
At the state level various state departments have developed maps for their use and all need to be referenced to a common system for continuity and ease of data exchange.

A.3 Local
If any local agencies wish to have their maps compatible with the state and federal agencies, they need to know the reference system and how to reference their maps to it.

B. TYPES OF GEODETIC CONTROL

There are three basic types of geodetic control: horizontal, vertical and gravity. The department does not perform gravity surveys, therefore, they will not be discussed in this manual. If information is required for gravity surveys, please consult the document by the Federal Geodetic Control Subcommittee titled “Standards and Specifications for Geodetic Control Networks”, dated September 1984.

B.1 Horizontal

All values for horizontal control in the United States are based on the horizontal control networks established by the National Geodetic Survey. Horizontal geodetic control data consist of distances, directions, and angles between control stations. This data is used to determine geodetic coordinates and azimuths. The geodetic coordinates (Latitude and Longitude) can be converted to other coordinate systems.

B.2 Vertical

Vertical control networks have been established to provide a means of referencing heights of stations above a specified surface. The height is measured along the direction of the plumb line between the point and the reference surface. The reference surface is the **geoid**, which closely approximates mean sea level. See page 2-18 for the definition of a geoid.

C. CHARACTERISTICS OF GEODETIC REFERENCE FRAMEWORKS

C.1 Monumentation and Field Descriptions

Geodetic stations are marked in the field by using man made monuments, landmarks or natural features. Most stations will be metal disks set in concrete post or bedrock outcrops. Some of the newer stations are being set with stainless steel rods driven to a point of some amount of refusal. The disk will contain stamping identifying the name of the station, the year established and establishing agency information. The actual point of the station will be marked in the disk.

Stability of a station is very important. The chances of any movement of the marker can be minimized by carefully selecting the station site and the method of construction. Monuments are more susceptible to vertical movement than horizontal movement.

A description of the station and any peripheral marks is very important for the ease of station recovery. A “To Reach” description telling how to reach the station from some local prominent feature should be included in the field description.

C.2 Field Measurements and Methods

Both terrestrial and satellite survey methods are used to determine geodetic positions of stations. These positions are normally expressed in latitude and longitude. These geodetic stations are also known as horizontal control stations, triangulation stations, or traverse stations. The geodetic coordinates are normally converted to the Illinois State Plane Coordinate System for local surveys like those done by and for IDOT. See Appendix C for a description of the Illinois State Plane Coordinate System.

Vertical geodetic stations are stations with accurate elevations. Normally, the orthometric height is known. The orthometric height is defined as the distance between the vertical reference surface (geoid) and the vertical geodetic station on the surface of the Earth measured along the plumb line between the two.

Terrestrial survey methods usually establish only horizontal or vertical information for a station. Satellite survey methods can provide a three-dimensional position for a station but the heights are usually less accurate than those determined by the terrestrial method.

C.3 Survey Accuracy

The accuracy of the reference framework should be established at a higher level of accuracy than that required by any project to be controlled by the framework. That way, any inaccuracies in the framework will not significantly affect less accurate measurements in a project. The framework can consist of known monument points or a new network of points established to bring control to a project site.

C.4 Density

The accuracy of points within a geodetic reference framework is spacing dependent. Because of random errors, the fewer stations established within a network the higher the accuracy of the network when all other things are equal.

C.5 Datums

All surveys, whether geodetic or not, must have a point, line or surface for reference. This reference is called a datum. The National Geodetic Reference System (NGRS) uses several datums of reference. For a horizontal reference, the NGRS uses a regular mathematical surface called an ellipsoid of revolution as a model of the Earth. All horizontal coordinates, approximately 300,000 stations in the United States, are referenced to an ellipsoid of revolution. The vertical datum has a different reference. It is based on the physical concept of mean sea level.

C.5.1 Horizontal Datums

Two horizontal datums are common in the NGRS. They are the North American Datum of 1927 (NAD27) and the North American Datum of 1983 (NAD83).

C.5.1.1 North American Datum of 1927 (NAD27)

The NAD27 uses Clarke's spheroid of 1866 as the ellipsoid of revolution. It was designed as the ellipsoid that was a best fit for the United States. The NAD27 is being phased out by the NGS and is not recommended for survey control.

C.5.1.2 North American Datum of 1983 (NAD83)

The NAD83 is a new mathematical adjustment that uses a re-defined figure of the Earth called the Geodetic Reference System of 1980 (GRS80). The GRS80 is Earth-centered and better approximates the true size and shape of the Earth. The NAD83 adjustment is more than twice as accurate as the NAD27 adjustment and is required by the department as a reference for all highway projects.

As a result of the NAD83 adjustment, all horizontal stations have been assigned new geodetic coordinates. The change to an Earth centered datum also accommodates the Global Positioning System derived coordinates. All surveys should make a reference to what datum was used.

C.5.2 Vertical Datums

Within the NGRS are two vertical datums. They are the National Geodetic Vertical datum of 1929 (NGVD29) and the North American Vertical Datum of 1988 (NAVD88). The vertical datum is not a mathematical surface like the ellipsoid of revolution. The vertical datums are referenced to the geoid. The geoid is defined as the equipotential surface of the Earth's gravity field which best fits mean sea level. The NGVD29, established by the NGS, contains about 585,000 permanent marks. The stations provide the primary vertical control network for the United States. The NAVD88 is a new adjustment with a new definition of the vertical datum. Even though the absolute heights may change significantly in some areas, the height differences between adjacent marks will only change in the millimeter range. All vertical surveys should make reference to what datum was used for the survey. NGVD29 is being phased out by the NGS and is not recommended for survey control. NAVD88 is a more accurate datum and is required for use on highway projects.

II. STANDARDS AND SPECIFICATIONS FOR GEODETIC CONTROL NETWORKS

A. CLASSIFICATIONS OF ACCURACY

A.1 Horizontal Control Networks

The Federal Geodetic Control Subcommittee for horizontal surveys in the United States has established classifications of accuracy. Based on accuracy, these standards certify that when points are established in any particular survey they will have datum values consistent with other points of the same classification. Classifications are not determined by observation closures within a survey, but by the ability of the new surveys to duplicate already established values. See Table 1 for a listing of the classifications for order and class of accuracy.

TABLE 1 DISTANCE ACCURACY STANDARDS

Classification	*Minimum distance accuracy*
A-Order	1:10,000,000
B-order	1:1,000,000
First-order	1:100,000
Second-order, class I	1:50,000
Second-order, class II	1:20,000
Third-order, class I	1:10,000
Third-order, class II	1:5,000

Resource: Standards and Specifications for Geodetic Control Networks, dated September 1984

A.2 Vertical Control Networks

The Federal Geodetic Control Subcommittee has established classifications of accuracy for vertical surveys in the United States. These classifications certify that the orthometric elevations of points of a survey have a specific relationship with all other points in that and other vertical surveys. See Table 2 for a listing of the classifications for order and class of accuracy.

TABLE 2 ELEVATION ACCURACY STANDARDS

Classification	*Maximum elevation difference for Loop or Line* Metric	English
First-order, class I	4 mm $\sqrt{K}$	$0.017\sqrt{M}$
First-order, class II	5 mm $\sqrt{K}$	$0.021\sqrt{M}$
Second-order, class I	6 mm $\sqrt{K}$	$0.025\sqrt{M}$
Second-order, class II	8 mm $\sqrt{K}$	$0.033\sqrt{M}$
Third-order	12 mm $\sqrt{K}$	$0.050\sqrt{M}$

K equals the distance in kilometers and M equals the distance in miles.

Resource: Standards and Specifications for Geodetic Control Networks, dated September 1984

B. ACCURACY STANDARDS

B.1 Horizontal Control Networks

The order and class that is stated for any point or set of points provides a relation of specific accuracy to other points in the survey. This relationship is expressed as a distance accuracy. The distance accuracy is the ratio of the relative positional error of a pair of control points to the horizontal separation of those points. See Table 1, page 2-5.

B.2 Vertical Control Networks

When expressing an order and class of accuracy as relating to vertical control points, the relation is expressed as an elevation difference. An elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along existing level routes.

To meet the requirements for the given classes of survey in both the horizontal and vertical accuracy standards, the surveyor must follow certain specifications or procedures when collecting the field survey data. The next section provides the specifications for various types of surveys.

C. SPECIFICATIONS FOR GEODETIC SURVEYS

C.1 Horizontal Control Networks

C.1.1 Triangulation

Triangulation is a survey method of extending horizontal control by measuring the angles of triangles formed by the control stations to be located. The angular observations need to be supported by the occasional base line measurement of one side of one of the triangles in the network. The department does not use triangulation procedures for establishing geodetic control, therefore, it will not be discussed in this manual. If information is required for triangulation surveys, please consult the document by the Federal Geodetic Control Subcommittee titled “Standards and Specifications for Geodetic Control Networks”, dated September 1984.

C.1.2 Traverse

Traverse is a measurement system comprised of joined distance and angle observations supported by occasional astronomic observations. Traverse procedures are used mainly to densify horizontal control for local surveys.

C.1.2.1 Network Geometry

For a traverse to meet a certain order of accuracy, criteria must be met in relation to spacing between points, the number of ties that must be made for azimuth checks, etc. See Table 3, page 2-8 for the details of the requirements for various orders of accuracy.

TABLE 3 **TRAVERSE**

Classification	*First-Order*	*Second-Order Class I*	*Second-Order Class II*	*Third-Order Class I*	*Third-Order Class II*
Station spacing not less than (km)	10	4	2	0.5	0.5
Horizontal angles					
Instrument	0.2"	1.0"	1.0"	1.0"	1.0"
No. of observations	16	12	8	4	2
Rejection limit from mean	4"	5"	5"	5"	5"
Length measurements Standard error	1 part in 600,000	1 part in 300,000	1 part in 120,000	1 part in 60,000	1 part in 30,000
Astronomical azimuths					
Number of courses between azimuth checks	6	12	20	25	40
Standard error	0.45"	0.45"	0.6"	1.0"	1.7"
Azimuth closure at azimuth check point not to exceed	1" per station or 1.7" √N	1.5" per station or 3" √N	2" per station or 4.5" √N	3" per station or 10" √N	8" per station or 12" √N
Position Closure:					
After azimuth adjustment closing error in position not to exceed	0.04m √K or 0.166ft √M or 1:100,000	0.08m √K or 0.333ft √M or 1:50,000	0.2m √K or 0.832ft √M or 1:20,000	0.4m √K or 1.665ft √M or 1:10,000	0.8m √K or 3.330ft √M or 1:5,000

K equals distance in kilometers, M equals distance in miles***, N*** equals number of traverse segments

Resource: Standards and Specifications for Geodetic Control Networks, dated September 1984

C.1.2.2 Instrumentation

All theodolites and electronic distance measuring instruments must be properly maintained to provide reliable measurements. Targets used for observing angles shall have a clearly defined center or point of sighting. Optical plummets or collimators shall be used to ensure the instrument is centered over the station to be observed.

C.1.2.3 Calibration Procedures

Theodolites shall be checked periodically (at least once a year) to make sure they are in good adjustment. All electronic distance-measuring instruments should be calibrated on known base lines at least once each year.

C.1.2.4 Field Procedures

Field procedures should be followed as shown in Table 3, page 2-8. The requirements for the various orders of accuracy are given. For first order work, the measurements should be made at night. If GPS equipment is being used, see Appendix F for specifications for field procedures.

C.1.2.5 Office Procedures

During the office processing of all traverse data, care should be taken to make sure that each traverse meets the criteria for the order of accuracy required to meet the needs of the survey.

C.1.3 Global Positioning System

The Global Positioning System (GPS) method of line measurement is a form of trilateration and traverse. Base lines are determined as well as the azimuth of the base line. See Section VII, page 2-26 of this chapter for details for GPS surveys.

C.2 Vertical Control Networks

Vertical control is established by making measurements using a leveling instrument to determine the elevation difference between points. Leveling is done to extend vertical control.

C.2.1 Network Geometry

The leveling network shall be tied to existing bench marks that have an order of accuracy equal to or better than the intended order of accuracy of the new survey being done.

C.2.2 Instrumentation

If performing first order leveling, only a compensator or tilting leveling instrument should be used along with one piece leveling rods with invar faces. Wood, metal or plastic leveling rods should only be used for third order work.

C.2.3 Calibration Procedures

Leveling instruments and leveling rods should be checked periodically to ensure they are in proper adjustment. A peg test should be run at least once a week.

C.2.4 Field Procedures

Field procedures should be followed as outlined in Table 4, page 2-10. IDOT will not normally perform leveling to first or second-order standards. If these orders of accuracy are required, refer to the Federal document by the Federal Geodetic Control Subcommittee titled “Standards and Specifications for Geodetic Control Networks”, dated September 1984.

TABLE 4 **LEVELING**

Classification	*First-Order Class I*	*First-Order Class II*	*Second-Order Class I*	*Second-Order Class II*	*Third-Order*
Spacing of marks along lines	1 to 3 km	1 to 3 km	1 to 3 km	Less than 3 km	Less than 3 km
Field Procedures					
Maximum difference in lengths	2 m	5 m	5 m	10 m	10 m
Forward & backward sights per setup	2 km	2 km	2 km	3 km	3 km
Section length, average (1)	50 m	60 m	60 m	70 m	90 m
Maximum length of sight					
Maximum Closure					
Section; forward and backward	3 mm √D or 0.013ft √M'	4 mm √D or 0.017ft √M'	6 mm √D or 0.025ft √M'	8 mm √D or 0.033ft √M'	12 mm √D or 0.05ft √M'
	4 mm √K or 0.017ft √M	5 mm √K or 0.021ft √M	6 mm √K or 0.025ft √M	8 mm √K or 0.033ft √M	12 mm √K or 0.05ft √M
Loop or line					

K equals the distance in kilometers and D equals the shortest length of section (one-way) in kilometers.

M equals the distance in miles and M' equals the shortest length of section (one-way) in miles.

(1) A loop or line consists of several sections that are double run.

Resource: Standards and Specifications for Geodetic Control Networks, dated September 1984

C.2.5 Office Procedures

During the office processing of all leveling data, care should be taken to make sure that each leveling line segment or loop closure meets the criteria for the order of accuracy required to meet the needs of the survey.

III. HORIZONTAL CONTROL

A. DATUMS

A.1 North American Datum of 1927 (NAD27)

The United States Coast and Geodetic Survey now known as the National Geodetic Survey (NGS) did the first adjustment of a national geographic positional system in 1927. This adjustment is based on a reference surface defined by Clarke's spheroid of 1866. A triangulation station, Meade's Ranch, in the central part of Kansas was assigned specific values in latitude and longitude. The azimuth line from Meade's Ranch to station Waldo was assigned a fixed value. All NAD27 geographic coordinates for the triangulation network established by the NGS was originally based on the values assigned to the station, Meade's Ranch.

A.2 North American Datum of 1983 (NAD83)

The North American Datum of 1983 is a readjustment of the geographic positions of the geodetic network of stations based on a reference ellipsoid defined by the Geodetic Reference System of 1980 (GRS80). New geodetic coordinates were produced for all horizontal control points in the network. The readjustment was done because the NAD27 values no longer provided the quality of horizontal control required by surveyors and engineers.

From 1927 until 1983 many years of geodetic observations were accomplished and added to the basic network. Technology improvement provided more accurate results. Additional base lines were measured using Electronic Distance Measuring Instruments (EDMI) and Very Long Baseline Interferometry (VLBI) technology. This all improved the internal consistency of the network.

A new definition of the ellipsoid (GRS80) that better approximates the Earth's true size and shape was developed. It replaced Clarke's spheroid of 1866 definition, which had been designed as a best fit for the shape of the Earth across North America.

The origin of the datum moved from station Meade's Ranch to the Earth's center of mass. This provides for a better compatibility with the satellite systems.

A.3 Datum Transformations

At times there may be a need to transform coordinate values in one datum to another datum. The NGS has software available (GPPCGP for NAD27 and SPCS83 for NAD83 to convert coordinates from latitude and longitude to state plane coordinates and the reverse. NADCON is a software program that converts geographic positions from an older NGS datum to NAD83. UTMS is a program to convert NAD83 latitude and longitude to UTM coordinates. The Corps of Engineers has combined the four programs mentioned above. It is called CORPSCON. It will transform coordinates between NAD27 and NAD83 for the following types of coordinate sets: Geographic, State Plane and Universal Transverse Mercator. CORPSCON also includes VERTCON to convert NGVD29 elevations to NAVD88 and reverse. This software is available from the Illinois Geodetic Advisor or from the NGS Web Site (www.ngs.noaa.gov). The software comes with documentation on how to run it.

B. PROJECTIONS

B.1 Transverse Mercator

The Transverse Mercator projection is a modification of the Mercator projection. It was designed for use in states with their greatest dimension lying in a north-south direction. The projection is used as the basis for the state plane coordinate system in Illinois.

The projection consists of a cylinder that has its axis rotated 90º from that used in the Mercator projection. In the Mercator projection the axis of the cylinder is coincident with the axis of the Earth. Its radius is slightly smaller causing it to cut the ellipsoid's surface along two meridians. See Figure 2.1, page 2-29 for an example of the Transverse Mercator projection.

The projection has the following characteristics:

- The scale of the projection is exact along the two meridians where the cylinder cuts the ellipsoid's surface.
- The scale is too large for the zones outside of the two meridians and too small for the zone included between the two meridians.
- The projection can be extended indefinitely in a north-south direction without changing the scale relations.
- The scale changes rapidly in an east-west direction.

B.2 Lambert Conformal Conic

The Lambert projection is a conic projection consisting of an imaginary cone whose central axis is assumed to be coincident with the axis of the earth. The surface of the cone cuts the surface of the ellipsoid at two standard parallels. It was designed for use in states with their greatest dimension in an east-west direction. See Figure 2.2, page 2-30 for an example of the Lambert Conformal Conic projection.

When the surface of the cone is developed into a plane surface the central meridian is given an assigned longitude. The projections from the Earth's surface onto the cone are made along radii from the Earth's center.

The projection has the following characteristic:

- The longitude scale along the standard parallels is exact.
- The conical surface is very nearly coincident with the Earth's surface. The latitude and longitude scales are so nearly exact that angles between lines on the projection are very nearly the same as the angles between the same lines on the Earth's surface.
- Between the standard parallels the scale of the projection is too small while outside of the standard parallels the scale is too large.
- The projection can be extended indefinitely in an east-west direction without affecting the accuracy of the projection.
- The scale changes very rapidly in a north-south direction.

B.3 Universal Transverse Mercator (UTM)

The Universal Transverse Mercator projection is a special case of the Transverse Mercator projection used as a basis for the UTM grid. The grid consists of 60 north-south zones, each 6º wide in longitude, with the longitudes of the boundary edges integral multiples of 6º. The longitudes of the central meridians are therefore odd multiples of 3º. The zones are numbered from 1 to 60 starting at 180º West Longitude and increasing easterly to 180º East Longitude. (Definitions of Surveying and Associated Terms, ACSM 1972).

C. COORDINATE SYSTEMS

C.1 Geodetic Coordinates

Geodetic coordinates are given in latitude and longitude, which define a position of a point on the surface of the earth with respect to the reference spheroid or *ellipsoid. They are also known as geographic coordinates.* (Definitions of Surveying and Associated Terms, ACSM 1972).

C.2 State Plane Coordinate System

The State Plane Coordinate System is a plane-rectangular coordinate system established by the U.S. Coast & Geodetic Survey, the predecessor of the National Geodetic Survey. A system has been designed for each state in the United States. It is used to define positions of geodetic stations in terms of a plane-rectangular (x and y) coordinate system. Most states are divided into areas called zones. Each zone has it own state plane coordinate definition.

One or more zones cover each state, over each of which is placed a grid imposed upon a conformal map projection. The relationship between the grid and the map projection is established by mathematical analysis. Zones of limited east-west dimension and indefinite north-south extent have the transverse Mercator map projection as the base for the state coordinate system. Zones for which the above order of magnitude is reversed have the Lambert conformal conic map projection with two standard parallels. Only adjusted positions on the North American datum of 1927 and 1983 may be transformed into plane coordinates on a state system. (Definitions of Surveying and Associated Terms, ASCM 1972.

The state plane coordinate system was designed to enable surveyors and engineers to connect their land or engineering surveys to a common reference system, NAD27 or NAD83. For more details on the state plane coordinate system and its development see the publication of NOAA Manual NOS NGS 5, State Plane Coordinate System of 1983, by James E. Stem.

The Department, as of August 1, 1988, has required the use of the geodetic coordinate values from the NAD83 adjustment. The requirement pertains to all projects using Illinois State Plane Coordinates as a coordinate system.

C.3 Universal Transverse Mercator (UTM) Coordinates

A plane-rectangular coordinate system designed for worldwide coverage between latitudes 84ºN and 80ºS. The polar areas are covered by the Universal Polar Stereographic (UPS) grid. (Definitions of Surveying and Associated Terms, ACSM 1972). The UTM coordinate system is not considered accurate enough for controlling highway projects in the department, because it covers large areas of the Earth's surface requiring a greater projection and therefore a larger distortion.

D. COORDINATE SYSTEM CONVERSIONS

Geodetic coordinates are not readily usable to the local surveyor who wants to use a plane-rectangular coordinate system for land surveys or engineering surveys. To be able to use a geodetic coordinate as published by the NGS, the geodetic coordinate must be converted to a plane-rectangular grid system. Two methods are used to do this. They are the Manual and Automated Methods.

D.1 Manual Method

The manual method of conversion is a combination of simple equations, tables and intermediate numerical input requiring only a calculator capable of basic arithmetic operations. See NGS Publication 303 for an example of how to convert a coordinate value manually.

D.2 Automated Method

The Automated method of conversion consists of equations that have been sequenced and structured to facilitate computer programming.

Because the equations apply equally to mainframe and programmable hand-held calculators, the availability of sufficient significant digits warrants consideration. To acquire a copy of the equations, contact the NGS. The NGS programs called NADCON, GPPCGP and SPCS83 written for the PC will convert geodetic coordinates to state plane coordinates. See page 2-12 for further information on these programs.

D.3 Direct Conversion (Geodetic to State Plane)

This computation starts with the geodetic coordinates of a point (latitude and longitude) from which the Transverse Mercator grid coordinates (N,E) are to be computed.

D.4 Inverse Conversion (State Plane to Geodetic)

In this computation the state plane grid coordinates in the Transverse Mercator system (N,E) are given and the geodetic coordinates are to be computed.

E. ILLINOIS PRIMARY HORIZONTAL CONTROL (PUBLISHED)

There are two federal agencies that are considered the primary sources of monumented horizontal control in Illinois. They are the National Geodetic Survey and the U. S. Geological Survey.

E.1 National Geodetic Survey (NGS)

The National Geodetic Survey has established thousands of control stations to first, second and third-order accuracy in Illinois. This information is published and available to the general public.

E.2 U.S. Geological Survey (USGS)

The U.S. Geological Survey has established monuments in Illinois in connection with its quadrangle mapping program. The USGS has mainly set third-order traverse stations. A few second-order traverse stations have been established using theodolites and EDMI. It is not recommended that USGS monuments be used for horizontal control of projects. The information is published and available to the general public.

F. ILLINOIS SECONDARY HORIZONTAL CONTROL

F.1 The Illinois Department of Transportation (IDOT)

The IDOT has been using state plane coordinates for several years to control highway projects. Most of the coordinates were established to third-order or better accuracy.

F.2 Other State Agencies

Several other state agencies have established state plane coordinates in conjunction with their construction projects. Two of those agencies are the State Water Survey and the Office of Water Resources within the Department of Natural Resources.

G. MONUMENTATION

G.1 National Geodetic Survey

G.1.1 3-Dimensional Rod Mark

A new style for a marker, known as the 3 Dimensional Rod, was designed by the NGS when it started using the Global Positioning System for establishing control stations. The 3-Dimensional rod mark is a mark consisting of a series of 4-foot long stainless steel rods linked together. These rods are driven into the ground with a powered reciprocating driver until the rod refuses to be driven further or the driving rate of 60 seconds per foot is reached. The top section in the freeze thaw area is lined with a sleeve to eliminate the effects of freezing and thawing on the rod. No disk is used on these marks. The top of the rod is rounded to provide a very precise height for elevation purposes and is accessed through a vault cover. See Figure 2.3, page 2-31 for an illustration of this type of mark.

G.1.2 Concrete Post

Concrete post can be used for monumenting high-order survey stations. The NGS normally sat a sub-mark under the surface mark for perpetuation. If the surface mark is bumped out of position or moved, the station can be replaced by setting a new surface mark over the sub-mark. See Figure 2.4, page 2-32 (Highway Standard number 668001) for the details of concrete monuments.

G.1.3 Drill Hole

Station disk can be set in drill holes made in rock outcropping, concrete bridge piers, etc. A hole is made with a drill and the disk is held in place with mortar or epoxy.

G.2 U.S. Geological Survey

The U. S. Geological Survey has been the primary mapping agency of the United States. They have run third-order and some second-order control for this purpose. Their primary traverse stations have been monumented with concrete monuments and disk. They have not and do not set sub-marks.

G.3 Illinois Department of Transportation (IDOT)

The IDOT uses concrete marks, either pre-cast or poured in place, to monument some of their traverse stations. Most of the stations have been marked by a 5/8-inch re-bar with a yellow plastic cap.

IV. VERTICAL CONTROL

A. DATUMS

A.1 National Geodetic Vertical Datum of 1929 (NGVD29)

The NGVD29 was established to provide vertical control in the United States. The general adjustment was originally known as the Sea Level Datum of 1929. *The datum is not mean sea level, the geoid, or any other equipotential surface. Therefore it was renamed, in 1973, the National Geodetic Vertical Datum of 1929.* (Geodetic Glossary by the National Geodetic Survey dated September

1986). Tide gauges were used in conjunction with thousands of kilometers of leveling lines to establish this datum.

A.2 North American Vertical Datum of 1988 (NAVD88)

The NAVD88 was established to replace the NGVD29. The NGVD29 adjustment had been modified many times by using additional data and making regional adjustments with the new data. Several of the older monuments had been destroyed by construction and widening of highways. A large number of the monuments had moved in elevation due to crustal movement, postglacial rebound or uplifting, and subsidence due to mining and withdrawal of underground liquids. The department, as of July 1, 1999, is requiring the NAVD88 to be used as the vertical datum of reference for all new surveys by and for the department.

A.3 Datum Transformations

A program has been developed for the conversion from the NGVD29 to the NAVD88 or the reverse. This program was written by the NGS and is called VERTCON. VERTCON is included in the Corps of Engineers program called CORPSCON.

B. GEOID

A surface that coincides with that surface to which the oceans would conform over the entire earth if free to adjust to the combined effect of the Earth's mass attraction and the centrifugal force of the Earth's rotation. It is an irregular surface that is perpendicular at every point to the direction of gravity (the plumb line). It is the surface of reference for astronomical observations and for geodetic leveling. See Figure 2.5, page 2-33 for an illustration of the geoid and its relationship to the ellipsoid and the Earth's surface. When performing Global Positioning System (GPS) computations, always indicate which Geoid Model was used in the processing of the data.

C. ILLINOIS PRIMARY VERTICAL CONTROL (PUBLISHED)

There are two federal agencies that are considered the primary sources of monumented vertical control in Illinois. They are the National Geodetic Survey and the U. S. Geological Survey.

C.1 National Geodetic Survey (NGS)

The National Geodetic Survey has established thousands of control stations to first and second-order accuracy in Illinois. This information is published and available to the general public.

C.2 U.S. Geological Survey (USGS)

The U.S. Geological Survey has established monuments in Illinois in connection with its quadrangle mapping program. These monuments were established to meet third-order accuracy. The USGS references its level lines to the National Geodetic Survey's First and Second-Order level lines. The information is published and available to the general public.

D. ILLINOIS SECONDARY VERTICAL CONTROL

D.1 The Illinois Department of Transportation (IDOT)

The IDOT establishes bench marks to control highway projects. These bench marks are established to third-order accuracy or less. Not very many permanent markers have ever been set. Contact the appropriate district survey office for information on IDOT bench mark information.

D.2 Other State Agencies

Several other state agencies have established bench marks in conjunction with their design and construction projects. Two of those agencies are the State Water Survey and the Office of Water Resources of the Department of Natural Resources. Their vertical control is normally done to third-order or less standards.

D.3 Army Corps of Engineers

The Army Corps of Engineers has established vertical monuments along the major navigable waterways. They are established to third-order standards and are available from the Corps of Engineers.

E. MONUMENTATION

E.1 National Geodetic Survey

E.1.1 3-Dimensional Rod Mark

See Section III, HORIZONTAL CONTROL, G.1.1, page 16 for details of the 3 Dimensional Rod Mark.

E.1.2 Concrete Post

See Section III, HORIZONTAL CONTROL, G.1.2, page 17 for details of the concrete mark.

E.1.3 Drill Hole

See Section III, HORIZONTAL CONTROL, G.1.3, page 17 for details on the drill hole.

E.2 U.S. Geological Survey

The U. S. Geological Survey is the primary mapping agency for the United States. They establish third-order control for this purpose. The bench mark stations have been monumented with concrete monuments and disks. At times they have used chiseled squares in headwalls and other concrete surfaces, punch holes in the ends of metal culverts and other semi-permanent objects.

E.3 Illinois Department of Transportation (IDOT)

The IDOT uses concrete marks, either pre-cast or poured in place, to monument some of its traverse stations. Most of the stations have been marked by a 5/8-inch re-bar with a yellow plastic cap. The iron pins can only be used as temporary bench marks during the project. They have no permanency.

V. SOURCES FOR OBTAINING CONTROL DATA

A. NATIONAL GEODETIC SURVEY

A.1 Headquarters

The National Geodetic Survey (NGS) is the primary source for obtaining horizontal and vertical geodetic survey information for the United States. The headquarters is located in Silver Spring, Maryland. The address is: US Department of Commerce, National Oceanic & Atmospheric Administration, National Ocean Service, National Geodetic Survey, Silver Spring, Maryland, 20910. Information can be obtained through their web site at: www.ngs.noaa.gov. Categories of information are: aeronautical data, CORS GPS data, data sheets, geodetic tool kits and PC software. All PC software listed is downloadable over the Internet. Data sheets for all points in the U.S. are available and can be downloaded for printing. Information on all operating CORS stations is available. The geodetic tool kit is a listing of available programs for performing geodetic conversions and other geodetic functions. The NGS web site is a very valuable resource for information. It provides several alternatives for searching for information.

A.2 Illinois Geodetic Advisor

The State of Illinois has a geodetic advisor located at the central IDOT office in Springfield. The address is: Illinois Geodetic Advisor, 2300 South Dirksen Parkway, Room 005, Springfield, Illinois 62764. The advisor is an employee of NGS and is on contract to the State. The advisor has all the information about the NGS horizontal and vertical monuments in Illinois and can furnish them to the surveyor upon request.

A.3 Formats

The descriptions for all stations in Illinois along with coordinates and azimuth information are available on a CD-ROM. This CD, which includes most of the adjoining states, is available from the NGS in Maryland.

A.3.1 Horizontal

The available descriptions provide all known information about the station, such as: coordinates, elevations, recovery data, type of monument, azimuths to other stations or objects, and notes on the last reported recovery of the station. See an example of a horizontal station in Figure 2.7-1 to 3, pages 2-35 to 2-37.

A.3.2 Vertical

The vertical descriptions are similar to the horizontal except that no horizontal data is provided. A latitude and longitude may be given but it is usually scaled from a quadrangle map. See an example of a vertical station in Figure 2.8-1 to 2, pages 2-38 to 2-39.

B. U. S. GEOLOGICAL SURVEY

B.1 Headquarters

The U. S. Geological Survey (USGS) also publishes horizontal and vertical information. The main office is in Washington DC. Regional centers are located across the U.S.

B.2 Mid-Continent Mapping Center

Information on the stations can be obtained from the USGS at the Mid-Continent Mapping Center in Rolla, MO. Indexing of the control data is based on the name of the original 15' quadrangle for which it was set. The horizontal and vertical data for Illinois can be purchased from the Rolla office.

B.3 Formats

The descriptions and pertinent data about each station in the USGS network are available in paper copy format.

B.3.1 Horizontal

The horizontal stations are of third-order or less accuracy and can not be used for controlling highway projects.

B.3.2 Vertical

Vertical control normally meets third-order accuracy. An example of USGS bench mark descriptions and station data is illustrated in Figure 2.9, page 2-40.

B.4 Illinois State Geological Survey

The Illinois State Geological Survey located in Urbana, IL is a distributor of the USGS quadrangle maps that are available in the 7.5 minute format for the entire state of Illinois. The Aerial Surveys Section has a complete set of USGS 7.5 minute quadrangles that are available for use on IDOT highway projects. The quadrangles for Illinois can now be purchased from the USGS in a digital format.

C. ILLINOIS DEPARTMENT OF TRANSPORTATION

C.1 Headquarters

The Illinois Department of Transportation (IDOT) establishes horizontal and vertical control for its highway projects to third-order or higher accuracy. Much of the control station information can be obtained from the Aerial Surveys Section in the central office in Springfield at 217-782-7627. The Aerial Surveys Section also has a complete set of station information for the NGS as well as the USGS markers.

C.2 Districts

Each of nine highway district offices has records of control stations established in its respective district. This information can be obtained from each individual district office.

C.3 Formats

The format for the control station information from IDOT is provided in hard copy format for both horizontal and vertical.

VI. MARK MAINTENANCE

A. PRESERVING MARKS

Although the survey marks are made of durable materials such as concrete, they are very susceptible to damage from various sources. It takes a concerted effort to maintain them in a usable condition. Even then, many of them are destroyed before they can be moved to a safer location. This section deals with the procedures and methods to help preserve the control monumentation that is available in Illinois.

A.1 Recovering Control Monuments

Anytime a station is used for a survey, recovery information should be recorded and passed on to the Illinois Geodetic Advisor who will forward it to the NGS main office in Maryland. Making recovery notes about a control station that has been recovered is instrumental in helping preserve the network of monuments that have been established for everyone to use.

A.2 Reporting Endangered Monuments

When recovering monuments and it is determined that the monument is in danger of being destroyed, it should be reported to the Illinois Geodetic Advisor immediately. Provide the name of the control station, the county in which it lies, and the type of endangerment.

A.3 Reporting Destroyed Monuments

When searching for and trying to recover a monument and are unable to locate it, report the information immediately to the Illinois Geodetic Advisor. Report the existing conditions at the site and any of the reference marks that are still in place. Include any other pertinent information that will help the geodetic advisor evaluate the destroyed control station.

A.4 Reporting Control Station Deficiencies

When recovering and using monuments always report any deficiencies about the control station and its description to the geodetic advisor. The advisor will forward this information to the main headquarters for inclusion in the published data about the station. This will help others when they try to recover the station at a later date.

B. HORIZONTAL CONTROL MONUMENTS

B.1 Rebuilding Surface Monuments

Many times when a surface monument is destroyed, the station position is not really lost. Normally, when the NGS sets monuments, an underground mark is set directly below the surface mark. If this underground mark has not been disturbed, a new surface mark can be set directly over the sub-mark again. Certain procedures are required to bring the control station back to the surface. The geodetic advisor should be consulted about performing this function.

B.2 Relocating Control Stations

If a control station is in danger of being disturbed or destroyed, contact the geodetic advisor about having it moved to a safer location. When reporting this to the geodetic advisor, it would be helpful if some possible relocation sites can be investigated before reporting the need for relocation.

B.3 Establishing Reference Marks

Destroyed reference marks should be reported to the geodetic advisor. The advisor will research the area and establish new mark(s) for the station.

B.4 Relocating Azimuth Marks

If an azimuth mark is in danger of being destroyed, it is best if the azimuth can be transferred to a new monument before the old one is destroyed.

B.5 Descriptions for New Monuments

Written descriptions for new monuments shall contain the following information: a "To Reach" description from some very prominent feature located in the nearest city or town; local ties made to natural objects near the monument; ties to the reference marks for the station and for the azimuth mark; a description of the type of material used in the monument and a description of how the mark is stamped.

B.6 Submittal of Data

All data collected while moving or re-establishing a monument should be forwarded to the geodetic advisor for review and submittal to the National Geodetic Survey for publication.

C. VERTICAL CONTROL MONUMENTS

C.1 Relocating Bench Marks

If the surveyor has information about a bench mark that is in danger of being destroyed or disturbed, it should be reported to the geodetic advisor immediately so arrangements can be made to relocate it. If the advisor is unable to respond to the urgency, instructions will be provided on what to do in the interim to assist in preserving the mark.

C.1.1 Direct Transfer of Elevation

The best procedure to preserve a mark is to transfer the elevation directly from one monument to the other. The level setups should be kept to a minimum. One setup is preferred. All three wires must be read and recorded in the prescribed manner acceptable by the NGS.

C.1.2 Indirect Transfer of Elevation

If there is no time to set a new mark before transferring the elevation, an indirect method may be used. This method requires setting at least three (3) temporary bench marks in the very near vicinity of the existing mark. Once the new mark has been set, the elevation can be determined by leveling from all temporary bench marks back to the new mark. Again, all three wires must be read and recorded.

C.2 Descriptions for Relocated Bench Marks

Written descriptions for new monuments shall contain the following information: an approximate mileage and direction from the nearest town; a "To Reach" description from some very prominent feature located in the nearest city or town; local ties made to natural objects near the monument; a description of the type of material used in the monument; and a description of how the mark is stamped.

C.3 Submittal of Data

All data collected while moving or re-establishing a monument should be forwarded to the geodetic advisor for review and submittal to the National Geodetic Survey for publication.

VII. ESTABLISHING CONTROL WITH THE GLOBAL POSITIONING SYSTEM

A. INTRODUCTION

The Global Positioning System (GPS) is a three-dimensional measurement system. It uses the radio signals of the NAVSTAR Global Positioning System developed by the Department of Defense. The system determines Cartesian coordinates based on the center of mass of the earth. These x, y, z coordinates are then converted to latitude and longitude and height above the reference ellipsoid. When connections are made to known vertical control, the height of the geoid can be determined and applied to the GPS heights to establish orthometric heights for points with unknown elevations.

The use of Global Positioning System equipment has become very popular. The full satellite constellation makes the use of GPS attractive to all surveyors because of its accuracy and capability in establishing horizontal and vertical control. The IDOT has established its own set of specifications for performing GPS surveys for the department. (See Item D, page 2-28 of this section for details about the specifications.) These GPS specifications are for control surveys using relative positioning techniques where two or more receivers are collecting satellite transmissions simultaneously.

B. CLASSIFICATIONS OF ACCURACY

B.1 Horizontal

The Federal Geodetic Control Subcommittee (FGCS) has established six classifications of accuracy standards. Those six classes are: AA, A, B, 1, 2, and 3. These classifications are normally referred to as orders of accuracy.

B.2 Vertical

No vertical classifications of accuracy have been developed by the FGCS as of this writing. The accuracy of the GPS developed elevation depends on the accuracy of the acquired GPS ellipsoid height, the accuracy of the orthometric heights of the known vertical control monuments, and the accuracy of the geoid-ellipsoid separation.

C. ACCURACY STANDARDS

C.1 Horizontal

Accuracy standards have been developed by the FGCS and are illustrated in Table 2.1, page 2-27.

TABLE 2.1

Survey Categories	Order	(95 percent confidence level) Minimum geometric Accuracy standard Base error e (cm)	Line-length Dependent error p (ppm)	a (1:a)
Global-regional geodynamics ; deformation measurements	AA	0.3	0.01	1:100,000,000
National Geodetic Reference System, “primary” networks; regional-local geodynamics; deformation measurements	A	0.5	0.1	1: 10,000,000
National Geodetic Reference System, “secondary” networks; connections to the “primary” NGRS network; local geodynamics; deformation measurements; high-precision engineering surveys	B	0.8	1	1: 1,000,000
National Geodetic Reference System (Terrestrial based); dependent control surveys to meet mapping, land information, property, and engineering requirements	(C)			
	1	1.0	10	1: 100,000
	2-I	2.0	20	1: 50,000
	2-II	3.0	50	1: 20,000
	3	5.0	100	1: 10,000

Note: For ease of computation and understanding, it is assumed that the accuracy for each component of a vector base line measurement is equal to the linear accuracy standard for a single-dimensional measurement at the 95 percent confidence level. Thus, the linear one-standard deviation (s) is computed by:

$$s = \pm \frac{\left[\sqrt{e^2} + \left(0.1d * p\right)^2\right]}{1.96}$$

Where, d is the length of the base line in kilometers.

Table 2.1 was taken from the Geometric Geodetic Accuracy Standards and Specifications for using GPS Relative Positioning Techniques by the Federal Geodetic Control Committee dated May 11, 1988.

C.2 Vertical

The FGCS has not developed standards, as of this writing, for developing elevations as they have for horizontal information. For all IDOT work see Specifications for GPS Surveys in Appendix F.

D. SPECIFICATIONS FOR GPS SURVEYS

The IDOT has developed a set of specifications for doing GPS surveys for IDOT. The specifications provides information on the procedures to follow, types of equipment to use and describes the various acceptable methods of controlling different types of surveys for the department. See Appendix F of this manual for the details of the specifications.

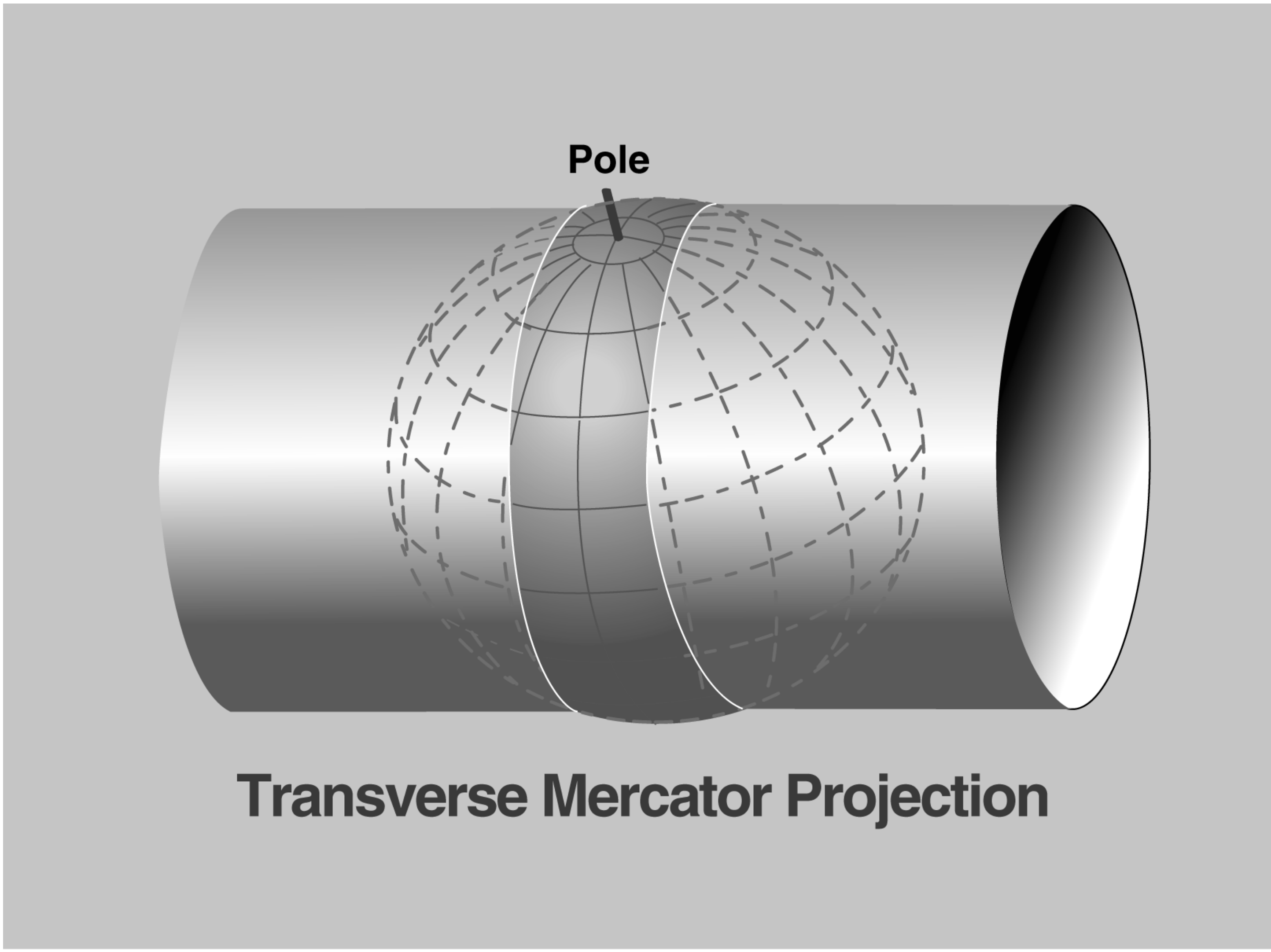


Figure 2.1

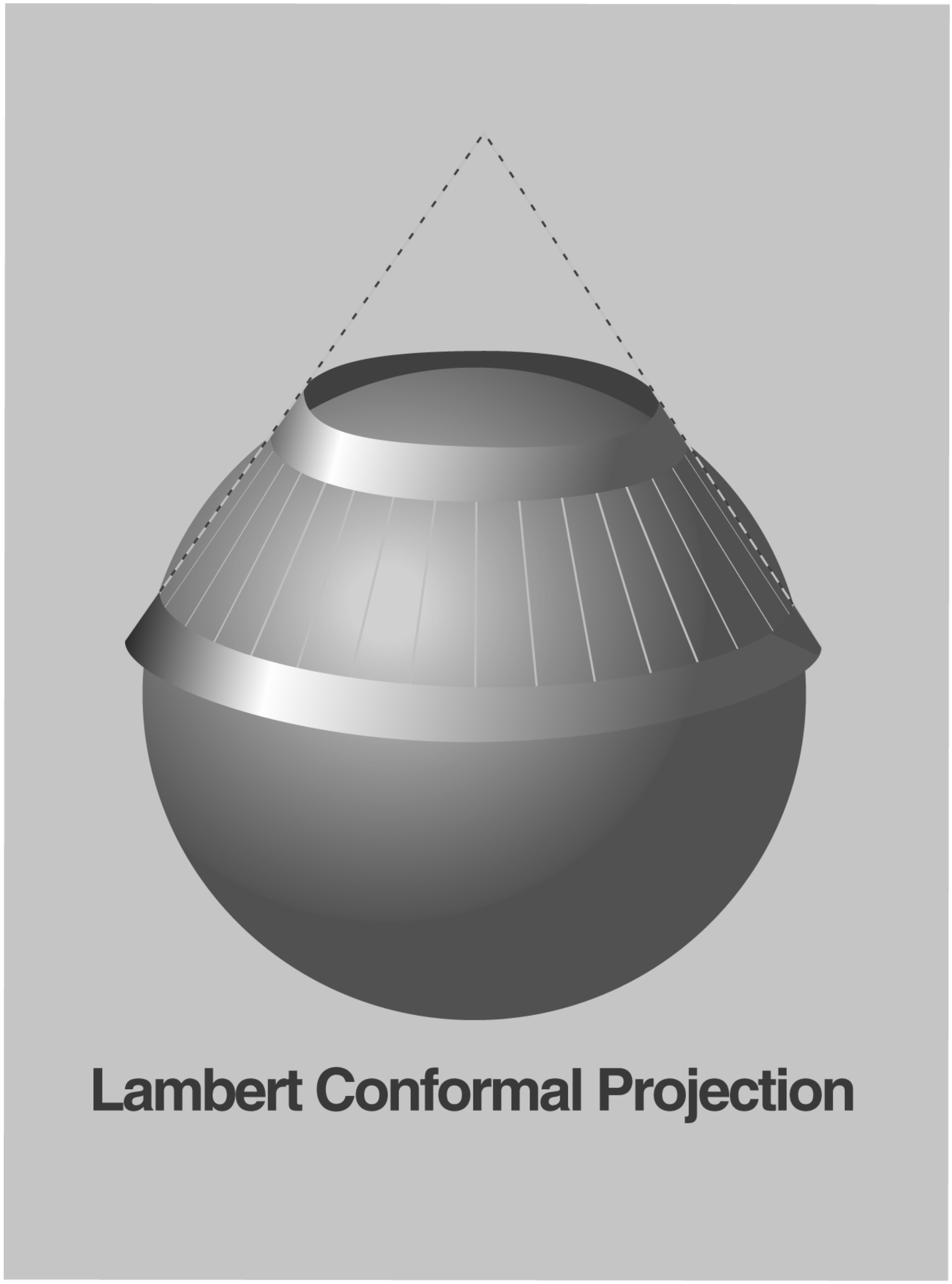
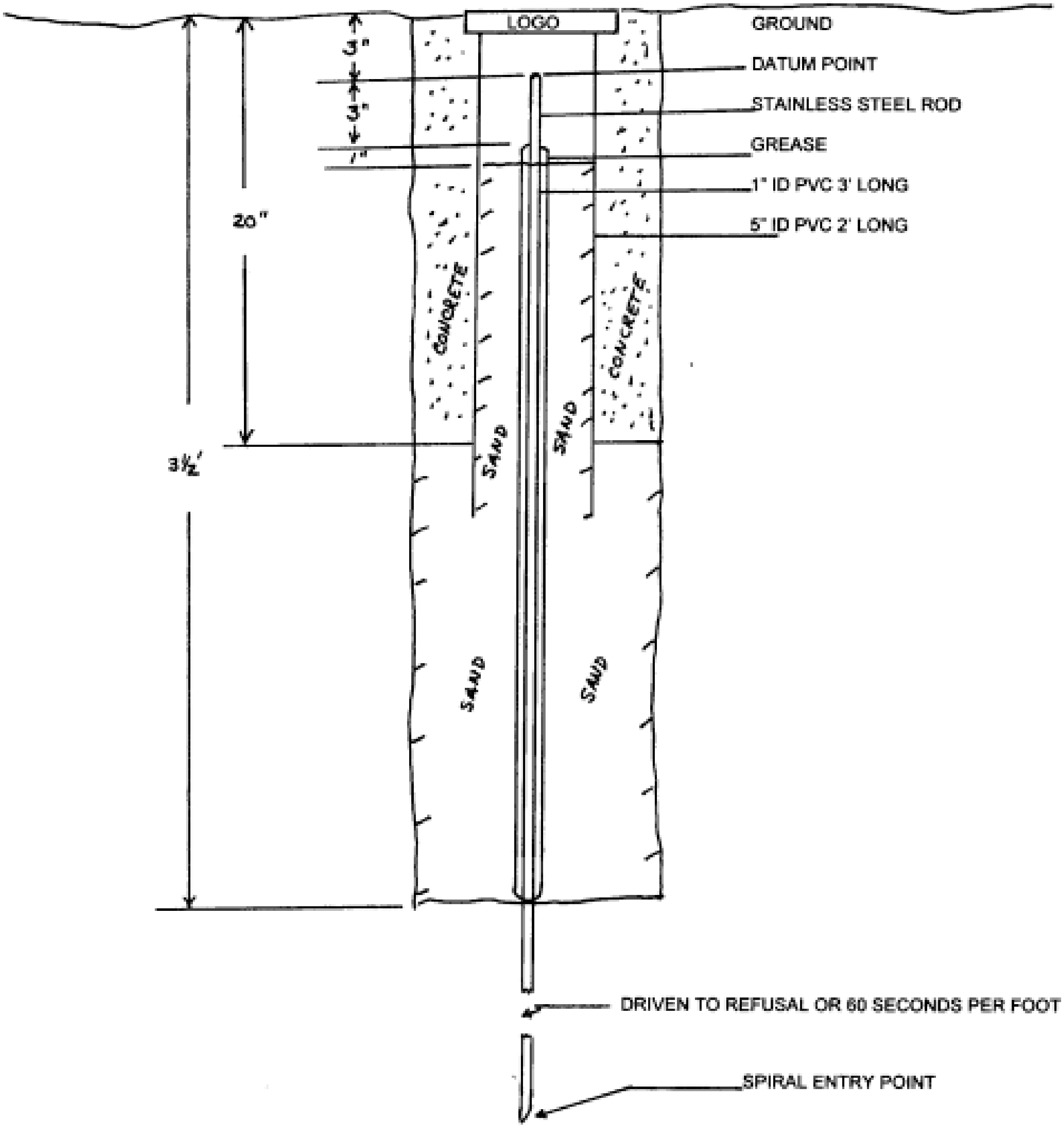
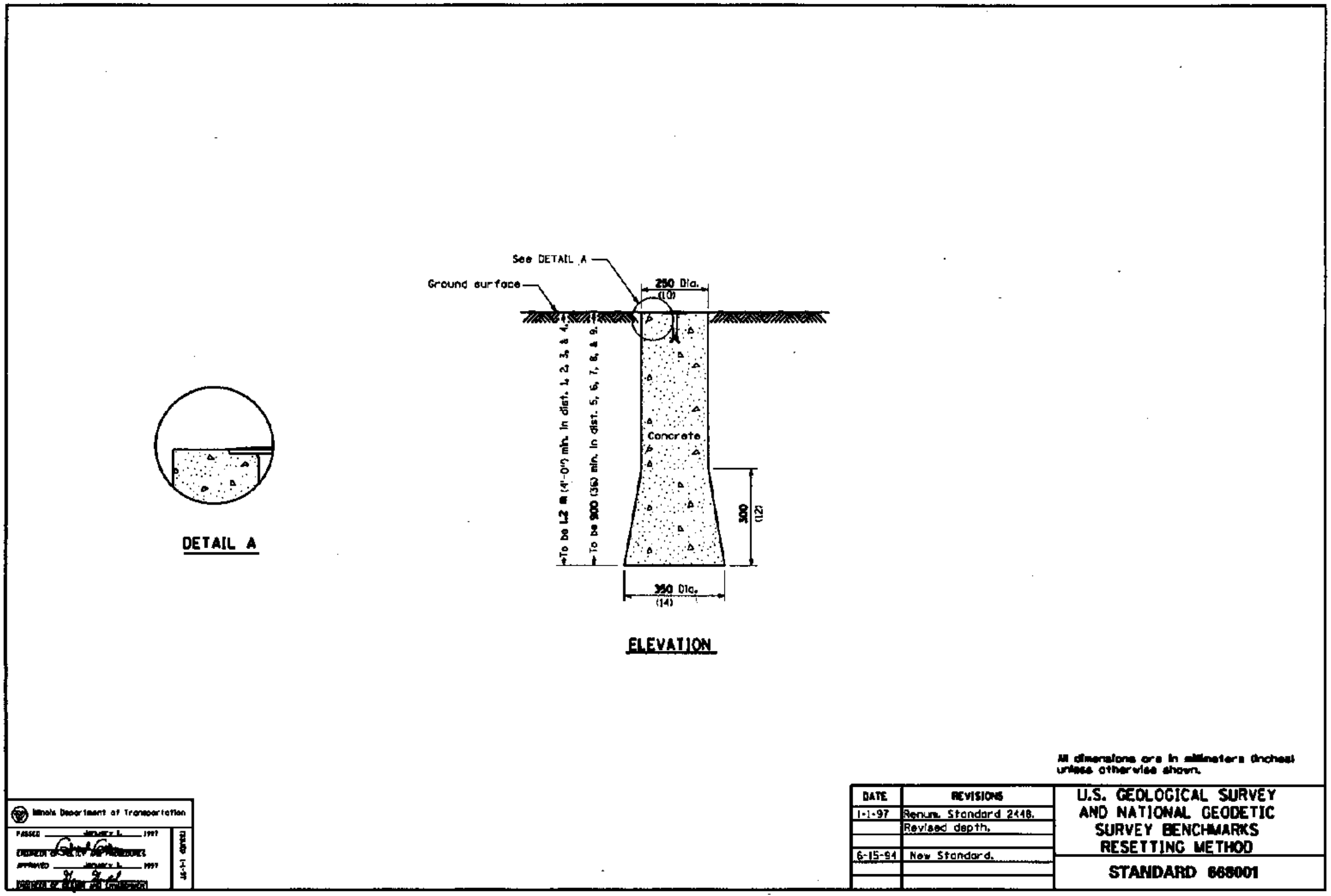


Figure 2.2



Schematic of the NGS 3-D marker

Figure 2.3



DETAIL A
See DETAIL A
Ground surface
250 Dia.
(10)
Concrete
To be 1.2 m (4'-0") min. in dist. 1, 2, 3, & 4.
To be 900 (36) min. in dist. 5, 6, 7, 8, & 9.
300
(12)
350 Dia.
(14)
ELEVATION
All dimensions are in millimeters (inches) unless otherwise shown.
DATE
REVISIONS
1-1-97
Renum. Standard 2448.
Revised depth.
6-15-94
New Standard.
U.S. GEOLOGICAL SURVEY
AND NATIONAL GEODETIC
SURVEY BENCHMARKS
RESETTING METHOD
STANDARD 668001
Illinois Department of Transportation

Figure 2.4

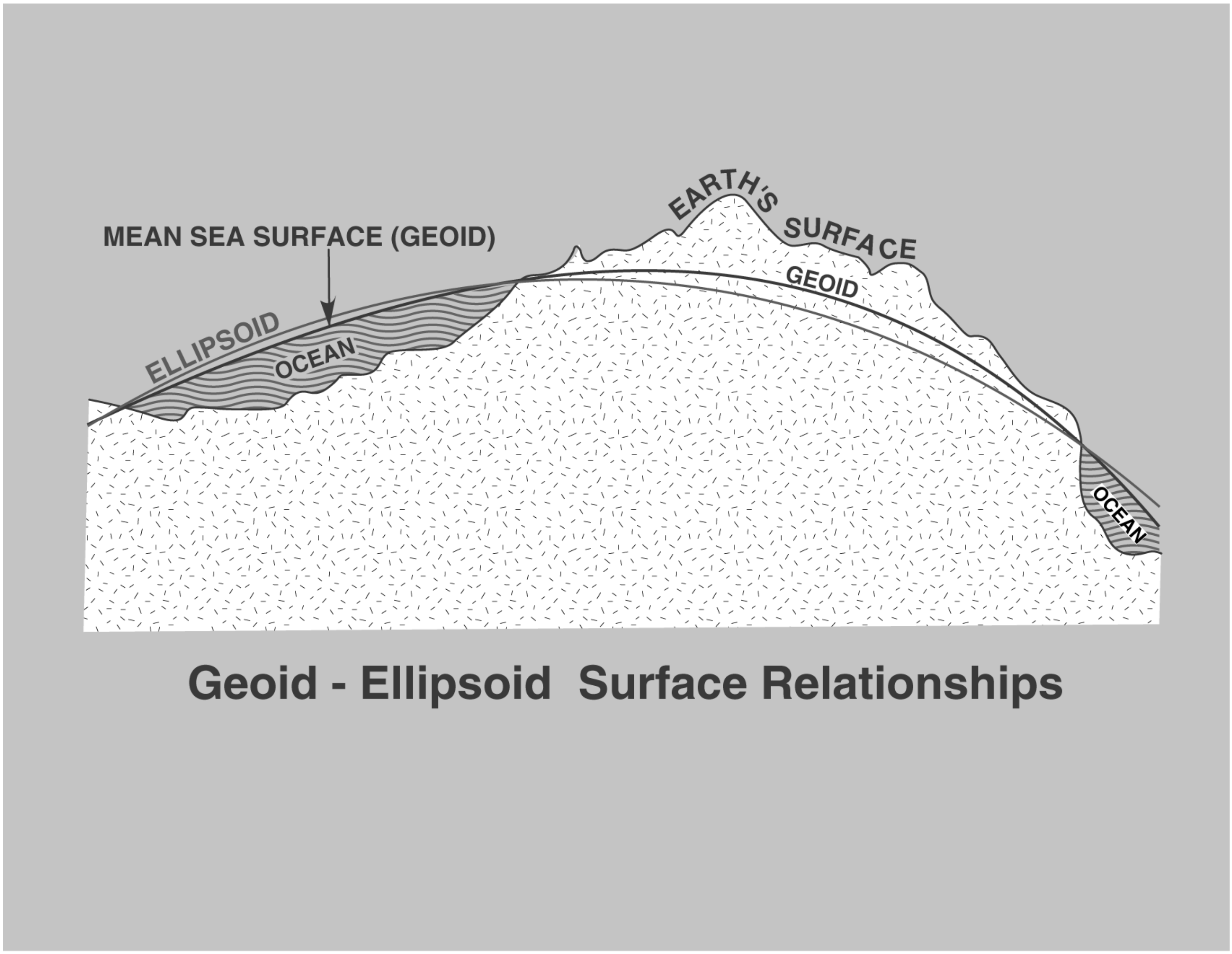

MEAN SEA SURFACE (GEOID)
EARTH'S SURFACE
GEOID
ELLIPSOID
OCEAN
OCEAN
Geoid - Ellipsoid Surface Relationships

Figure 2.5

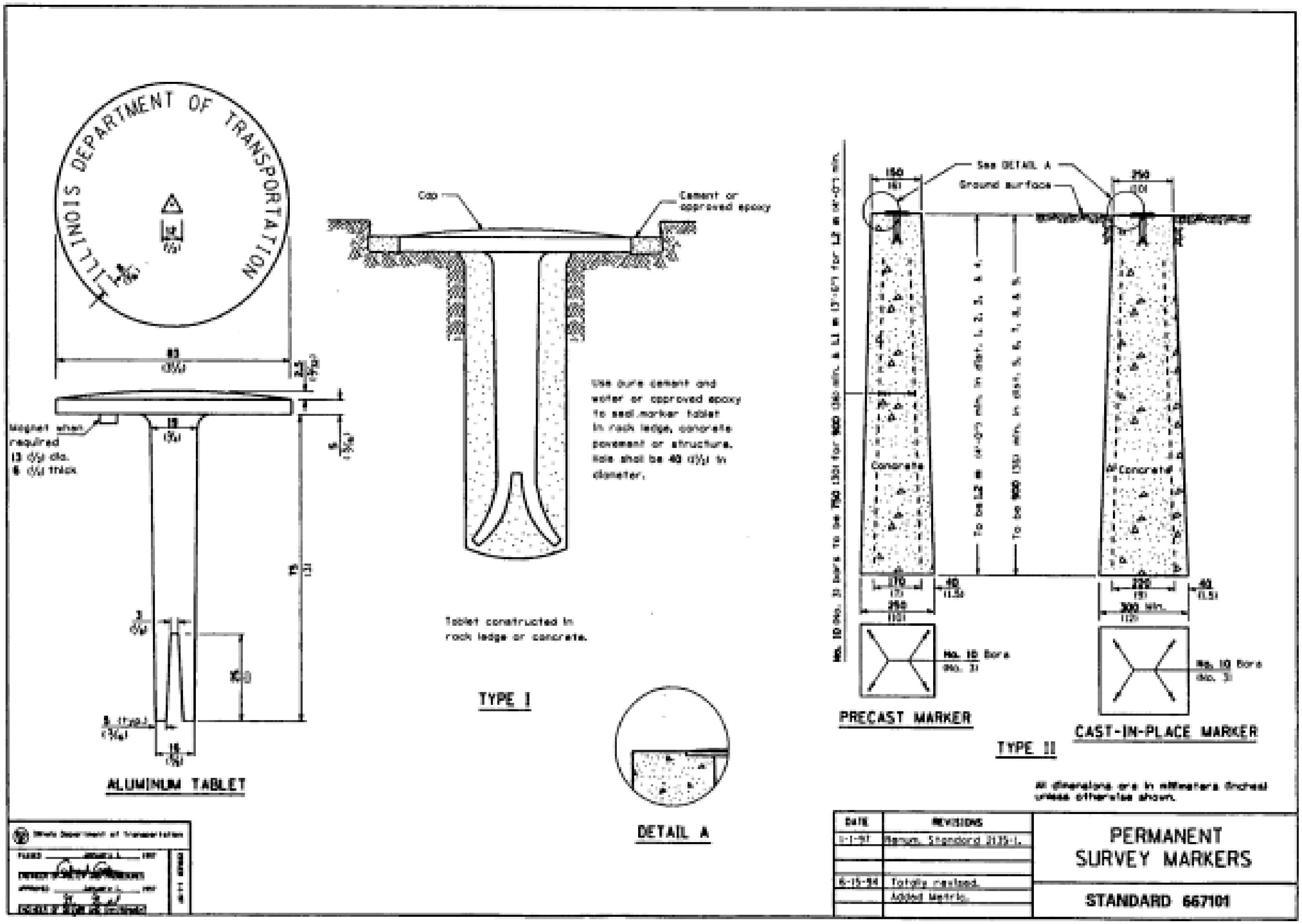

ILLINOIS DEPARTMENT OF TRANSPORTATION
Magnet when required
ALUMINUM TABLET
Cap
Cement or approved epoxy
Use pure cement and water or approved epoxy to seal marker tablet in rock ledge, concrete pavement or structure. Hole shall be 40 (1½) in diameter.
Tablet constructed in rock ledge or concrete.
TYPE I
DETAIL A
See DETAIL A
Ground surface
Concrete
No. 10 Bars
PRECAST MARKER
CAST-IN-PLACE MARKER
TYPE II
All dimensions are in millimeters (inches) unless otherwise shown.
PERMANENT SURVEY MARKERS
STANDARD 667101
Totally revised.
Added Metric.

Figure 2.6

```
1       National Geodetic Survey,   Retrieval Date = OCTOBER 28, 1998
LC2060 ***********************************************************
LC2060  CBN            -    This is a Cooperative Base Network Control Station.
LC2060  PACS           -    This is a Primary Airport Control Station
LC2060  DESIGNATION    -    LINCPORT
LC2060  PID            -    LC2060
LC2060  STATE/COUNTY   -    IL/LOGAN
LC2060  USGS QUAD      -    LINCOLN EAST (1980)
LC2060
LC2060                          *CURRENT SURVEY CONTROL
LC2060  ___________________________________________________________________
LC2060* NAD 83 (1997) -    40 09 32.06927 (N)    089 20 07.04372 (W)ADJUSTED
LC2060* NAVD 88       -        179.17    (meters)   587.8    (feet)   GPS OBS
LC2060___________________________________________________________________
LC2060  X             -        56,630.391      (meters)            COMP
LC2060  Y             -    -4,881,130.781      (meters)            COMP
LC2060  Z             -     4,091,580.934      (meters)            COMP
LC2060  LAPLACE CORR  -             1.58       (seconds)           DEFLEC96
LC2060  ELLIP HEIGHT  -           146.69       (meters)            GPS OBS
LC2060  GEOID HEIGHT  -           -32.39       (meters)            GEOID96
LC2060
LC2060  HORZ ORDER    -          B
LC2060  ELLP ORDER    -    FOURTH              CLASS I
LC2060
LC2060. This mark is at Logan County Airport  (3LC)
LC2060
LC2060.The horizontal coordinates were established by GPS observations
LC2060.and adjusted by the National Geodetic Survey in July 1998.
LC2060.This is a SPECIAL STATUS position.  See SPECIAL STATUS under the
LC2060.DATUM ITEM on the data sheet items page.
LC2060
LC2060.The orthometric height was determined by GPS observations.
LC2060
LC2060.GPS derived orthometric heights for airport stations designated as
LC2060.PACS or SACS are published to 2 decimal places.  This maintains
LC2060.centimeter relative accuracy between the PACS and the SACS.  It does
LC2060.not indicate centimeter accuracy relative to other marks which are
LC2060.part of the NAVD 88 network.
LC2060
LC2060.The X, Y, and Z were computed from the position and the ellipsoidal ht.
LC2060
LC2060.The Laplace correction was computed from DEFLEC96 derived deflections.
LC2060
LC2060.The ellipsoidal height was determined by GPS observations
LC2060.and is reference to NAD 83.
LC2060
LC2060.The geoid height was determined by GEOID96.
LC2060
```

Figure 2.7-1

```
LC2060;                  North         East       Units   Scale   Converg.
LC2060;SPC IL W    -  387,962.709    770,825.881   MT   1.00000291 +0 32 10.3
LC2060;UTM  16     -  4,448,009.417  301,113.827   MT   1.00008696 -1 30 23.6
LC2060
LC2060:               Primary Azimuth Mark                      Grid Az
LC2060:SPC IL W    -  LINCPORT AZ MK                            034 45 10.9
LC2060:UTM  16     -  LINCPORT AZ MK                            036 47 44.8
LC2060
LC2060 ------------------------------------------------------------------------
LC2060  PID           Reference Object         Distance          Geod. Az
LC2060                                                           dddmmss.s
LC2060  LC2061        LINCPORT AZ MK          441.969  METERS    0351721.2
LC2060 ------------------------------------------------------------------------
LC2060
LC2060                           SUPERSEDED SURVEY CONTROL
LC2060
LC2060  NAD 83 (1986) -     40 09 32.08155 (N)    089 20 07.03942 (W)AD(    ) 1
LC2060  NGVD 29       -          179.2     (m)          588.    (f)     GPS OBS
LC2060
LC2060.Superceded values are not recommended for survey control.
LC2060.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
LC2060.See file format.dat to determine how the superceded data were derived.
LC2060
LC2060-MARKER: I = METAL ROD
LC2060-SETTING: 59 = STAINLESS STEEL ROD IN SLEEVE  (10 FT. +)
LC2060-STAMPING:  LINCPORT 1990
LC2060_PROJECTION:  RECESSED 4 CENTIMETERS
LC2060_STABILITY:  B = PROBABLY HOLD POSITION/ELEVATION WELL
LC2060_SATELLITE:  THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
LC2060+SATELLITE:  SATELLITE OBSERVATIONS – May 05, 1997
LC2060_ROD/PIPE-DEPTH:  9.4  meters
LC2060_SLEEVE-DEPTH  :  1.0  meters
LC2060
LC2060  HISTORY       -       Date        Condition              Recov. By
LC2060  HISTORY       -       1990        MONUMENTED             NGS
LC2060  HISTORY       -   19970505        GOOD                   NGS
LC2060
LC2060                           STATION DESCRIPTION
LC2060
LC2060'DESCRIBED BY NATIONAL GEODETIC SURVEY 1990
LC2060'STATION IS LOCATED ABOUT 3.0 KM (1.9MI) NORTHEAST OF LINCOLN, AT THE
LC2060'LOGAN COUNTY AIRPORT, IN THE NORTH ANGLE OF THE JUNCTION OF THE PAVED
LC2060'RUNWAY AND THE RAMP, IN EAST CENTRAL SECTION 29, T 20 N, R 2 W.
LC2060'OWNERSHIP—LOGAN COUNTY BOARD, ATTENTION AIRPORT MANAGER, ROUTE 4
LC2060'AIRPORT ROAD, LINCOLN, IL 62556.  CURRENT ACTING AIRPORT ATTENDANT IS
LC2060'SAM EVANS, PHONE 217-732-3333.
LC2060'TO REACH FROM THE JUNCTION OF INTERSTRATE HIGHWAYS 55 AND 55 BUSINESS
LC2060'(EXIT 133) AT THE NORTHEAST END OF LINCOLN, GO SOUTHWEST ON HIGHWAY
LC2060'55 BUSINESS (OLD HIGHWAY 66) FOR 2.36 KM (1.47 MI) TO A PAVED ROAD
LC2060'LEFT.  TURN LEFT ON WINDING ROAD, SOUTHWESTERLY, ON HIGHWAY 55
LC2060'BUSINESS FOR 0.63 KM (0.39 MI) TO A PAVED ROAD LEFT.  TURN LEFT,
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Figure 2.7-2

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LC2060'EAST, ON ROAD 1700 N FOR 0.19 KM (0.12 MI) TO A PAVED ROAD RIGHT.
LC2060'TURN RIGHT, SOUTH, FOR 0.73 KM (0.45 MI) TO ROAD END AT GATE AT
LC2060'HANGERS, NORTHEAST TO APRON THEN SOUTHEAST ON MAIN CONNECTING RAMP
LC2060'FOR 0.34 KM (0.21 MI) TO THE RUNWAY AND THE STATION ON THE LEFT.
LC2060'THE STATION IS LOCATED 34.1 M (111.9 FT) NORTHWEST FROM THE CENTER OF
LC2060'THE RUNWAY, 21.5 M (70.5 FT) NORTHEAST FROM THE CENTER OF THE RAMP,
LC2060'AND 9.0 M (29.5 FT) EAST-NORTHEAST FROM A 2.7 X 0.9 METER CONCRETE
LC2060'PAD SUPPORTING AN ILLUMINATED RAMP/3-21 SIGN.
LC2060'NOTE—ACCESS TO DATUM POINT IS THROUGH A 5-INCH LOGO CAP.
LC2060
LC2060                       STATION RECOVERY (1997)
LC2060
LC2060'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1997  (CSM)
LC2060'THE STATION IS LOCATED 3.0 KM (1.85 MI) NORTHEAST OF LINCOLN, IL, AT
LC2060'THE LOGAN COUNTY AIRPORT, IN THE GRASS, NEAR AND NORTH OF THE
LC2060'NORTH ANGLE OF THE JUNCTION OF RUNWAY 21-3 AND TAXI/RAMP A, JUST
LC2060'EAST-NORTHEAST OF THE RUNWAY 21-3 SIGN.  OWNERSHIP—LOGAN COUNTY
LC2060'BOARD, AIRPORT MANAGER, AIRPORT ROAD, LINCOLN, IL 62656.  CURRENT
LC2060'ACTING AIRPORT ATTENDANT SAM EVANS, PHONE 217-732-3333.  NOT—THIS
LC2060'STATION IS THE PACS AND FBN/CBN STATION.  TO REACH THE STATION FROM
LC2060'THE JUNCTION OF INTERSTATE HIGHWAY 55 AND 55 BUSINESS (EXIT 133) NEAR
LC2060'THE NORTHEAST EDGE OF LINCOLN, GO SOUTHWEST, 2.36 KM (1.45 MI) ALONG
LC2060'55 BUSINESS (OLD HIGHWAY 66) TO (2400 N KICKAPOO ST) ON THE LEFT.  TURN
LC2060'LEFT, SOUTHWESTERLY, 0.63 KM (0.40 MI) ALONG WINDING KICKAPOO STREET
LC2060'(BUSINESS 55) TO (AIRPORT RD.) ON THE LEFT.  TURN LEFT, EAST, 0.19 KM
LC2060'(0.10 MI) ALONG AIRPORT ROAD TO THE AIRPORT ENTRANCE ROAD ON THE
LC2060'RIGHT.  TURN RIGHT, SOUTHERLY, 0.73 KM (0.45 MI) ALONG THE ENTRANCE
LC2060'ROAD TO A GATE.  PASS THROUGH THE GATE, SOUTHWEST, THEN LEFT,
LC2060'SOUTHEAST, THEN LEFT, NORTHEAST, ALONG THE SHORT TAXIS TO THE APRON.
LC2060'BEAR RIGHT, NORHTEAST, ACROSS APRON THEN SOUTHEAST, ALONG TAXI/RAMP
LC2060' A TO THE HOLD BARS AT A RUNWAY 21-3 IDENTIFIER SIGN AND THE STATION ON
LC2060'THE LEFT, JUST EAST-NORTHEAST OF THE SIGN.  STATION IS 34.1 M (111.9 FT)
LC2060'WEST-NORTHWEST OF THE RUNWAY CENTER, 21.5 M (70.5 FT)
LC2060'NORTH-NORTHEAST OF THE TAXI/RAMP CENTER, 9.0 M (29.5 FT)
LC2060'EAST-NORTHEAST OF THE NORTH-NORTHEAST CONCRETE BASE CORNER OF THE
LC2060'21-3 SIGN, AND THE STATION IS ABOUT LEVEL WITH THE TAXI/RAMP A AND
LC2060' RECESSED ABOUT 4-CM BELOW THE GROUND SURFACE.  BY R.G. HAYES NOTE—
LC2060' THE DATUM POINT IS A CENTER PUNCH ON THE TOP OF A STAINLESS STEEL ROD
LC2060' RECESSED ABOUT 10-CM BELOW THE GROUND SURFACE AND DRIVEN TO A DEPTH
LC2060' OF 9.4 M, (30.8 FT) IN A GREASE FILLED SLEEVE 1.0 M (3.3 FT) LONG,
LC2060' ENCASED IN A      5-INCH PVC PIPE WITH NGS LOGO CAP SURROUNDED BY
CONCRETE.  LC2060' ACCESS TO THE DATUM POINT IS THROUGH THE 5-INCH LOGO CAP.
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Figure 2.7-3

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1       National Geodetic Survey,        Retrieval Date = OCTOBER 28, 1998
KB0660***********************************************************************
KB0660  DESIGNATION   -     B13
KB0660  PID           -     KB0660
KB0660  STATE/COUNTY  -     IL/SANGAMON
KB0660  USGS QUAD     -     MECHANICSBURG (1983)
KB0660
KB0660                              *CURRENT SURVEY CONTROL
KB0660
KB0660* NAD 83(1986)  -     39 51 11.      (N)       089 24 30. (W)      SCALED
KB0660* NAVD 88       -       185.990      (meters)    610.20 (feet)   ADJUSTED
KB0660
KB0660  GEOID HEIGHT  -        -32.27      (meters)                       GEOID96
KB0660  DYNAMIC HT    -        185.893     (meters)    609.88  (feet)     COMP
KB0660  MODELED GRAV  -     980,096.0      (mgal)                         NAVD 88
KB0660
KB0660  VERT ORDER    -     FIRST CLASS II
KB0660
KB0660.The horizontal coordinates were scaled from a topographic map and have
KB0660.an estimated accuracy of +/- 6 seconds.
KB0660
KB0660.The orthometric height was determined by differential leveling
KB0660.and adjusted by the National Geodetic Survey in June 1991.
KB0660
KB0660.The geoid height was determined by GEOID96.
KB0660
KB0660.The dynamic height is computed by dividing the NAVD 88
KB0660.geopotential number by the normal gravity value computed on the
KB0660.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
KB0660.degrees latitude (G = 980.6199 gals.).
KB0660
KB0660.The modeled gravity was interpolated from observed gravity values.
KB0660
KB0660;                    North        East      Units  Estimated Accuracy
KB0660;SPC IL W       -   353,950.   764,890.      MT  (+/- 180 meters Scaled)
KB0660
KB0660                         SUPERSEDED SURVEY CONTROL
KB0660
KB0660  NGVD 29       -     186.086 (m)         610.52   (f)   ADJ UNCH  1 2
KB0660
KB0660.Superseded values are not recommended for survey control.
KB0660.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
KB0660.See file format.dat to determine how the superseded data were derived.
KB0660
KB0660_MARKER: DB = BENCH MARK DISK
KB0660_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT (ROUND)
KB0660_STAMPING: B 13 1933
KB0660_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
KB0660+STABILITY: SURFACE MOTION
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Figure 2.8-1

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KB0660
KB0660  HISTORY       - Date       Condition          Recov. By
KB0660  HISTORY       - UNK        MONUMENTED         CGS
KB0660  HISTORY       - 1933        GOOD              NGS
KB0660  HISTORY       - 1944        GOOD              NGS
KB0660
KB0660                            STATION DESCRIPTION
KB0660
KB0660'DESCRIBED BY NATIONAL GEODETIC SURVEY 1933
KB0660'AT BUFFALO.
KB0660'AT BUFFALO, SANGAMON COUNTY, ON THE WABASH RAILROAD, ABOUT 150
KB0660'FEET WEST OF THE STATION, 45 FEET WEST OF A CROSS STREET, 15 FEET
KB0660'WEST OF A BRICK SIDEWALK, 25 FEET NORTH OF THE MAIN TRACK, AND 5
KB0660'FEET WEST OF POLE 400/9. A STANDARD DISK, STAMPED B 13 1933 AND
KB0660'SET IN THE TOP OF A CONCRETE POST.
KB0660
KB0660                            STATION RECOVERY (1944)
KB0660
KB0660'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1944
KB0660'RECOVERED IN GOOD CONDITION.
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Figure 2.8-2

2
39-088-44
DECATUR QUADRANGLE
128 - ILLINOIS

LINE 1

K.E. Daly, 1966; Book CV-1986 DECATUR QUAD. – 128

0.0 Decatur, about 0.1 mi S. along Illinois Central RR. from the Wabash Station at, in sec. 21,T. 16 N., R. 3 E., thence about 4.1 mi SE. along U.S. Hwy. 36 from crossing of I.C. RR. at Junction of U.S. Hwy. 36 and State Hwy. 121 S., 29.5 ft N. of center of W. bound lanes of U.S. Hwy. 36, 66 ft NE. of center of junction of State Hwy. 121 and W. bound lanes of Hwy.36, 61 ft E. of center of asphalt road N. to Decatur Airport, 43 ft S. of S. rail of mainline of Baltimore & Ohio RR. track, 7 ft S. of S. edge of 5 ft manhole cover; in a concrete post flush with ground, a USC&GS standard disk stamped “X 262 1961” (Recovered in good condition) 671.468

0.7 UE X 262 A, 0.75 mi S. along State Hwy. 121 from tablet, T. 16 N., R. 3 E., near S. sixteenth cor. between secs. 28 and 29; 510 ft N. and 30 ft W. of Hwy. at road E.; 1 ft S. of N. end of W. headwall of 12 ft concrete box culvert; a chiseled square 643.20

1.8 Mt. Zion, 1.5 mi N. and 0.3 mi E. of, 1.7 mi S. along State Hwy. 121 from junction of U.S. 36, T. 16 N., R. 3 E.; near center W1/2. sec. 33, 22.5 ft N., 39.5 ft E. and 2.8 ft higher than Hwy. at E.-W. road, in a concrete post projecting 2-in., a City of Decatur Dept. public property tablet stamped “33 658 33” (Elev. by USGS) 658.119

1.8 Reference mark, 386.5 ft S. of tablet, 30 ft E. of road, N. and of E. headwall of 2 ft concrete box culvert; chiseled square 650.23

2.7 UE 33 A, 1 mi S. along Hwy. from tablet, at offset E.-W. road, T. 15 N., R. 3 E., near N. sixteenth cor. between secs. 3 and 4, 17 ft N., 30 ft W. and 0.9 ft higher than T-rd. W. of offset crossroads, center of N. concrete headwall of 1.5 ft culvert; chiseled square 688.71

3.7 UE 33 B, 2 mi S. along State Hwy. 121 from tablet, at road leading W. to Mt. Zion, T. 15 N., R. 3 E., near cor. Secs. 3, 4, 9 and 10, 250 ft NW. along RR., 10 ft NE. of center of RR. and 2.1 ft lower than RR. at E.-W. road crossing; center of N. end and 1 ft S. of N. edgeof old concrete semaphore base; chiseled square 697.43

5.2 At Hervey City, on the Pennsylvania RR., at the crossing of State Hwy. 121, 16.5 Poles W. of milepost 84, 30 ft N. of main track, 27 ft E. of edge of pavement; the top of a valve set in the top of a concrete post, stamped “BM 8” (ISHD) (Recovered as described in good condition) 699.073

LINE 2

K.E. Daly, 1966; Book CV-1986 DECATUR QUAD. – 128

0.0 Decatur, about 0.1 mi S. along I.C. RR. from the Wabash Station at, thence about 4.1 mi SE. along U.S. Hwy. 36 from the crossing of the I.C. RR., thence about 0.95 mi N. along asphalt road known as the airport road, in sec. 21, T. 16 N., R. 3 E., set in top of SW. cor. of the 6 x 10 ft concrete box around and over water mains for the airport, 240 ft SW. of SW. cor. Of the service hangar; 88 ft E. of the center of the asphalt road known as the airport road, 19 ft S. of the extended centerline of Cantrell St. leading W., about 4-in, above ground, a USC&GS standard disk stamped “Z 262 1961” 676.557

0.7 Antioch, 1.6 mi N. and 0.5 mi W. of, 1.6 mi N. of junction of State Hwy. 121 and U.S. Hwy. 36, at intersection of Mt. Zion Road and N. country Club Road; T. 16 N., R. 3 E., near quarter cor. between secs. 16 and 17, 33.5 ft S., 43 ft E. and 1.5 ft higher than T-street S., in a concrete post projecting 2-in., a City of Decatur Dept. Public Property tablet stamped “17-671.77” (Elev. by USC&GS) 671.471

Figure 2.9